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Effects of Calyx Coating and Storage Temperature on Antioxidant Substances of Cape Gooseberry (*Physalis Peruviana* L.)

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ABSTRACT

Cape gooseberry is a climacteric, temperature-sensitive fruit from the *Solanaceae* family. Its quality and quantity are characterized by phenolic and antioxidant substances, the stability of which depends on temperature and storage conditions. In this research, the effects of calyx cover (fruits without calyx cover and fruits covered with calyx) and storage conditions were evaluated on the storage life of Cape gooseberry fruits. For this purpose, the fruits were kept in with and without calyx conditions at three temperature levels of 10, 15, and 20 °C for 30 days. The results showed that, at the end of storage, the titratable acidity, total soluble solids, vitamin C, total flavonoid, and total antioxidants decreased significantly. However, total phenol content and flavor index increased during the storage period. The increase in total flavor and phenol content during storage can be due to a significant reduction in the titratable acidity (as reflected in the flavor index), because of cellular destruction and cold damage. In addition, at the end of the storage period, the calyx-covered fruits which were stored at 10 °C had good physicochemical and antioxidant qualities. The highest titratable acidity (0.633%), soluble solids (14.96%), vitamin C, and total antioxidants (59.33%) were observed in fruits covered with calyx at 10 °C. Also, the results of this study showed that storing berries at cooler temperatures increased the shelf life and maintained the quality of the Cape gooseberry.

Introduction

Consumers around the world are increasingly demanding high-quality food with longer shelf life and less chemical preservatives. There are constant efforts to develop natural antimicrobials and preservatives for the purpose of consumer satisfaction. Various storage techniques are used to increase the shelf life of fruits and vegetables after harvest (Athmaselvi et al. 2013). The storage duration is one of the most important post-harvest processes because unsafe storage conditions are sometimes the critical causes of quality and quantity damage to fruits. Most horticultural products are stored in conventional warehouses and a small amount are in commercial cold storage facilities (Tabatabae Koloor, 2012). Storing fruits in a low-temperature warehouse slows the physiological metabolism, maintains the quality of the fruit, and increases the shelf life of the fruits (Han et al., 2006).

Physalis peruviana L. is known by common names such as Cape gooseberry, peruvian groundcherry, ground cherry, or golden berry. It belongs to the Solanaceae family (Martinez, 1998) and is native to the South American Andes (Fischer and Melgarejo, 2014). The berries of this plant have high nutritional value due to their high vitamin content, minerals and antioxidants (Ramadan and Mörsel, 2019). In addition, the fruits of these plants are used in traditional medicine for the control of hepatitis, malaria, rheumatism,

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dermatitis diabetes, and weight loss (Akbaba, 2019).

Yellow-colored fruits are covered with calyx, which protects the fruits against insects, birds, diseases, and unsuitable weather conditions. The calyx plays a nutritional role after fruit harvesting (Puente et al., 2011). The climacteric fruits produce a large amount of ethylene during maturation, which plays an important role in the maturation process of fruits (Gutierrez et al., 2008). During storage, temperature management is the most important tool for increasing longevity and maintaining the quality of fruits and vegetables. The delay between harvesting and cooling or processing can lead to loss of water (directly) and change in taste (indirectly) in fruits and vegetables (Seung et al., 2000). The physiological traits at different stages of fruit maturity were documented in earlier research, indicating that harvesting the fruits at an appropriate stage of maturity can be suitable for the postharvest stage. When the calyx dried at 24°C and the fruit was stored at 12°C, the quality of fruits and the acidity were in the best condition compared to yellowish-green berries (Novoa et al., 2006). Fruits harvested in the immature stage and/or in full maturity will be exposed to physiological damage during the post-harvest and storage phases and the quality of the fruit will be lower than the berry harvested at the maturity stage (Kader, 2002). Similarly, storage at low temperatures is the most important option for decelerating fruit deterioration (Tellez et al., 2007). Cooling tools such as refrigerators are used to reduce respiration rates, which preserve fruit quality and delay senescence because respiration also decreases by cold storage (Silva et al., 2013). In cape gooseberry, studies on storage period have been conducted at temperatures of 7 °C (Lanchero et al., 2007), and 1.5 °C (Alvarado et al., 2004), in which the importance of refrigeration in the postharvest preservation of this species was aptly managed.

While seeking to explore the effects of the calyx cover and storage temperature on antioxidant substances and physicochemical traits in the Cape gooseberry, this study aimed to evaluate the antioxidant activity, the concentrations of vitamin C, phenolic compounds, and TSS, as well as their variations during storage at three different temperatures. The hypothesis of the work is based on the fact that the calyx coating on berries can retain physicochemical and antioxidant properties during storage.

Materials and Methods

Location and experimental method

To perform this experiment, the mature berries of Cape gooseberry were harvested from the Research Greenhouse of the University of Mohaghegh Ardabili and transferred to the laboratory. After removing the calyx (only for berry without calyx cover), and after washing the berries and removing their surface moisture, the berries were packaged either with calyx cover or without calyx cover (20 berries per package). They were kept for 30 days in the refrigerator and separate rooms at temperatures of 10, 15, and 20 °C. This research was conducted as a factorial experiment in a completely randomized design with three replications. The factors under assessment were, namely, the calyx (i.e. berry without a calyx coating and berry covered with calyx), the period of storage (zero time (initiation of storage), 15 and 30 days storage), and storage temperatures at three levels (10, 15, and 20 °C). Sampling the berries was performed at three stages (newly harvested berries, and those that were stored for 15 or 30 days). After starting the storage (every 15 days a month), the quantitative and qualitative traits of the berries were examined. These traits were TSS, TA, vitamin C, total phenol, total flavonoid, and total antioxidants.

Total soluble solids (TSS), titratable acidity (TA), and fruit flavor index

Total soluble solids (TSS) were measured using a refractometer (K-0032 manufactured in Japan) and the amount of soluble solids was recorded in terms of brix grade. To measure titratable acidity, titration was performed with 0.1 N NaOH. Titratable acid was expressed as grams per 100 ml of tartaric acid. For this purpose, 10 ml of berry juice was mixed with 20 ml of distilled water and was then titrated (Ayala et al., 2004). Using equation 1, the amount of titratable acid was obtained.

Equation (1): $A= ((S\times N\times E)/C) \times 100$

A: The organic acids content in the fruit extract ($g.100ml^{-1}$), S: The amount of NaOH consumed (ml), N: Normality of NaOH, F: The factor or normal coefficient for NaOH is 1, C: The amount of fruit extract (ml), E: equivalent desired acid (tartaric acid).

Fruit flavor index or sugar / acid ratio, which determined the taste of berry, was evaluated using the ratio of total soluble solids (S) to titratable acid (A), using equation 2, (Dissa et al., 2008).

Equation (2): $I= S/A$

Vitamin C

Measurement of vitamin C was carried out by titration with iodine in potassium iodide. The end of titration was when the color of the extract of the berry was dark blue and this color remained steady for several seconds (Arya, 2000).

Measurement of total phenols, total flavonoids, and total antioxidants

The berries of Cape gooseberry were dried in an oven at 55 °C for 48 hours before being ground in a mortar and pestle. One g of each sample was soaked in 50 ml of 80% methanol and stored at room temperature for 48 hours. Subsequently, the extracts were filtered with Whattman No. 4 filter paper. The solvents evaporated at a temperature below 50 °C. The remainder was kept at 4 °C for the rest of the experiments (Pour Morad et al., 2006).

Total phenol content

To measure the amount of total phenol, 2 ml of sodium carbonate (2%), 2.8 ml of distilled water, and 100µl reagent Folin Ciocalteau (50%) were added to 100µl of the extract. After half an hour, using a spectrophotometer, the absorbance was recorded at a wavelength of 720 nm. Gallic acid was used as a standard for drawing a standard curve. The total phenol content of each extract was reported based on mg. g-1 of Gallic acid per gram of dry matter (Meda et al., 2005).

Total flavonoid content

Total flavonoid content was measured using an aluminum chloride reagent. Accordingly, 1.5ml of methanol (80%), 100µl of aluminum chloride solution (10%), 100µl of sodium acetate 1 M, and 2.8ml of distilled water were added to 500µl of each extract (10 mg ml-1). The absorbance of the solution was measured 40 minutes after incubation at room temperature, at 415 nm, compared to the control sample (without extracts). Quercetin was used as a reference solution for drawing a standard curve. The total flavonoid content of each extract was expressed as mg of quercetin per gram of dry weight (Mita et al., 1997).

Antioxidant extraction

Free radical-scavenging activity was measured by the use of a stable DPPH radical. The DPPH radical-scavenging activity was determined using a method described by Miliauskas et al., 2004. To assay the total amount of antioxidants according to DPPH (Miliauskas et al., 2004), different concentrations of the extract were mixed with 2 ml of DPPH (0.004% methanolic solution). The control solution contained 2 ml of DPPH and 2 ml of methanol. The solutions were stored in the dark for 30 minutes at room temperature. The absorption of each sample was read at 517nm against methanol as the control. Free radical inhibition percentage (I%) of each extract was calculated by Equation (3):

Equation (3): % inhibition = ((Abs control - Abs test)/ Abs control) × 100

Statistical analysis

All data were initially subjected to analysis of variance (ANOVA), and mean comparisons were made by Duncan's multiple range test ($P < 0.05$). Data from each assessment date were individually analyzed with each treatment as the main factor and the block as a random factor. All statistical analyses were conducted using SAS 9.3 (SAS Institute Inc., Cary, NC, USA).

Results

Titratable acidity, soluble solids, flavor index

The titration of acidity in both levels of calyx coating decreased over time (Table 1). Although the titratable acidity in the Cape gooseberry reduced during storage, in berries with calyx at 10 °C, the reduction was lower than in other treatments. The highest titratable acidity (0.633%) was observed after 30 days of storage in berries with calyx at 10 °C, which had no significant difference with the amount after 15 days of storage. In addition, the lowest titratable acidity (0.294 %) was observed after 30 days of storage and in berries without calyx coating at 20 °C (Table 1).

A comparison of mean values regarding the effects of storage time, calyx coating and temperature treatments on soluble solids of Cape gooseberry showed a significant difference between the data of this trait from zero (first sampling) to 30 days after storage, and the amount of the soluble solids decreased during the storage period (Table 1). This decrease was more tangible in the berries without calyx under treatments at temperatures of 20 °C and 15 °C. The sharpest decrease in soluble solids was observed after 30 days of storage in berries without calyx at 20 °C. However, the decrease in soluble solids slowed down in the berries with calyx at different temperatures during storage. The berries with calyx at 10 °C after 30 days of storage had the lowest decrease in soluble solids content (Table 1).

Table 1. The interaction between storage time, calyx, and storage temperature on the amount of TA, TSS, and TSS/TA in Cape gooseberry fruits

calyx	storage time (day)	storage temperature	TA (%)	TSS (%)	TSS/TA (%)
-	0	-	0.760 a ± 0.0100	17.066 a ± 0.2516	22.443 g ± 0.5499
With calyx	15	10°c	0.659 b ± 0.0121	16.33 b ± 0.4163	24.783 fg ± 0.6635
		15°c	0.628 bc ± 0.0577	16.066 b ± 0.8962	25.573 f ± 1.5519
		20°c	0.596 c ± 0.0431	17.666 a ± 0.2886	29.696 e ± 1.6129
	30	10°c	0.429 e ± 0.0268	13.433 d ± 0.4041	31.340 de ± 1.4648
		15°c	0.387 ef ± 0.0210	12.633 ef ± 0.1527	32.636 cd ± 1.4063
		20°c	0.337 gh ± 0.0210	11.533 gh ± 0.2516	34.210 cd ± 1.4174
Without calyx	15	10°c	0.663 b ± 0.0572	14.966 c ± 0.2081	22.680 fg ± 1.9555
		15°c	0.506 d ± 0.0115	14.466 c ± 0.2516	28.566 e ± 1.1150
		20°c	0.403 ef ± 0.0316	13.566 d ± 0.2516	33.803 cd ± 3.2195
	30	10°c	0.373 fg± 0.0167	12.966 de ± 0.2081	34.803 c ± 1.5709
		15°c	0.337 gh ± 0.0168	12.100 fg ± 0.2000	35.946 ab ± 1.4319
		20°c	0.294 h ± 0.0125	11.266 h ± 0.2081	38.323 a ± 1.8471
ANOVA					
C			**	**	**
DS			**	**	*
TS			**	**	**
DS*C			**	*	ns
TS*C			ns	Ns	ns
TS*DS			**	*	*
TS*DS*C			**	**	**

DS: Duration of storage (day), C: calyx, TS: storage temperature. The same letter within each column indicates no significant difference among treatments using Duncan's Multiple Range Test. ns: not significant, *P < 0.05, **P < 0.01.

Flavor index was regarded as the ratio of soluble solids to titrated acid. This index increased at all three storage temperatures in berries with or without calyx during the storage period, so that the lowest flavor index was observed in the first step of sampling (Table 1). Although the flavor index increased during the storage period, the rate of increase slowed down in berries with calyx at 10 °C, compared with the other treatments. However, the highest flavor index (38.23%) was observed after 30 days of storage in berries without calyx at 20 °C (Table 1).

Vitamin C

The results showed that a prolonged storage time caused a decrease in the vitamin C content in berries. Meanwhile, the highest amount of vitamin C was observed in the first sampling at the beginning of the storage period. In addition, according to Table 2, after 30 days of storage, berries with calyx showed a smaller decrease in vitamin C, compared to berries without calyx. Also, as shown in Table 2, the amount of vitamin C decreased as the temperature increased during storage. However, during storage, the lowest level of vitamin C was observed in treated berries at a temperature of 10 °C after 30 days of storage.

Total phenol content

Generally, the total phenol content during storage was affected by temperature. Compared to the first stage of sampling, the total phenol content increased at first but then decreased (Table 3). Therefore, after 15 days of storage, the berries without calyx at 10 °C had phenolic compounds that were higher than berries with calyx under different temperatures. However, the highest amount of total phenol content was observed in berries with calyx at 10 °C after 30 days of storage. In addition, the lowest total phenol content was observed in berries without calyx after 30 days of storage at 20 °C (Table 3).

Total antioxidants

In general, antioxidant capacity decreased over the storage period at all levels of temperature and calyx treatments. The lowest antioxidant capacity (41.33%) was observed in berries without calyx at 20 °C, 30 days after storage. According to the comparison of mean values (Table 3), the 10 °C treatment significantly reduced the amount of antioxidant capacity during storage.

Table 2. The interaction between storage duration and calyx on vitamin C content of the Cape gooseberry fruits.

calyx	storage time (day)	storage temperature	vitamin C (mg 100g^{-1} Fw)
-	0	-	81.233 a ± 1.3919
With calyx	15	-	63.322 b ± 4.5430
	30	-	48.888 c ± 4.5995
Without calyx	15	-	57.293 bc ± 2.8002
	30	-	41.666 cd ± 3.3376
-	-	-	-
-	0	-	61.233 a ± 1.4375
-	15	10°c	64.250 b ± 4.8591
-		15°c	60.371 bc ± 3.1727
-		20°c	56.302 bc ± 2.5873
-	30	10°c	49.883 c ± 5.2522
-		15°c	44.750 cd ± 3.1181
-		20°c	41.200 d ± 3.9456
ANOVA			
C			**
DS			**
TS			ns
DS*C			**
TS*C			ns
TS*DS			**
TS*DS*C			ns

DS: Duration of storage (day), C: calyx, TS: Storage temperature. The same letter within each column indicates no significant difference among treatments using Duncan's Multiple Range Test. ns: not significant, *P < 0.05, **P < 0.01.

Table 3. The interaction between storage time, calyx, and storage temperature on the content of phenolic substances and total antioxidants in Cape gooseberry fruits

calyx	storage time (day)	storage temperature	Total flavonoid (mg. g^{-1} FW)	Total phenol (mg. g^{-1} FW)	Total antioxidant (%)
-	0	-	-	4.060 b ± 0.2551	74.496 a ± 0.8357
With calyx	15	10°c	-	2.866 c ± 0.2916	62.700 c ± 0.5082
		15°c	-	2.580 cd ± 0.1509	58.941 d ± 0.8156
		20°c	-	2.146 ef ± 0.0702	55.570 ef ± 0.0818
	30	10°c	-	3.803 b ± 0.1357	57.756 de ± 5.5674
		15°c	-	2.336 de ± 0.2311	48.030 g ± 1.6185
		20°c	-	1.736 g ± 0.1814	42.630 h ± 0.1311
Without calyx	15	10°c	-	4.826 a ± 0.2440	59.330 d ± 0.5634
		15°c	-	2.260 de ± 0.6928	55.793 ef ± 0.5892
		20°c	-	2.0366 fg ± 0.0493	54.143 f ± 0.6312
	30	10°c	-	2.826 c ± 0.4067	52.590 fg ± 0.3372
		15°c	-	1.776 fg ± 0.2836	47.046 g ± 0.3971
		20°c	-	0.850 h ± 0.1600	41.331 h ± 0.6744
ANOVA					
C					
DS			**	ns	**
TS			**	**	**
DS*C			ns	**	**
TS*C			ns	**	*
TS*DS			ns	ns	**
TS*DS*C			ns	**	*

DS: Duration of storage (day), C: calyx, TS: Storage temperature. The same letter within each column indicates no significant difference among treatments using Duncan's Multiple Range Test. ns: not significant, *P < 0.05, **P < 0.01.

Even though the decrease of total antioxidant capacity in berries with calyx was sharper than those without calyx after 15 days of storage, the total antioxidant capacity in berries with calyx was higher than berries without calyx after 30 days of storage (Table 3).

Content of flavonoids

According to the results of analysis of variance, regarding total flavonoid content (Table 3), only the main effects of storage time and calyx coating on total flavonoid content were significant at 1% probability level (Table 3). The comparison of mean values showed that with a longer storage time, the flavonoid content decreased in berries. The highest amount (5 mg. g^{-1} FW) of flavonoid content was observed in the first stage of sampling, i.e. immediately after harvest, and the lowest amount was observed after 30 days of storage (Fig. 1a). In addition, the comparison of mean values regarding the main effects of the calyx coating showed that the berries with calyx had the highest flavonoid content (5.54 mg. g^{-1} FW) during storage (Fig. 1b).

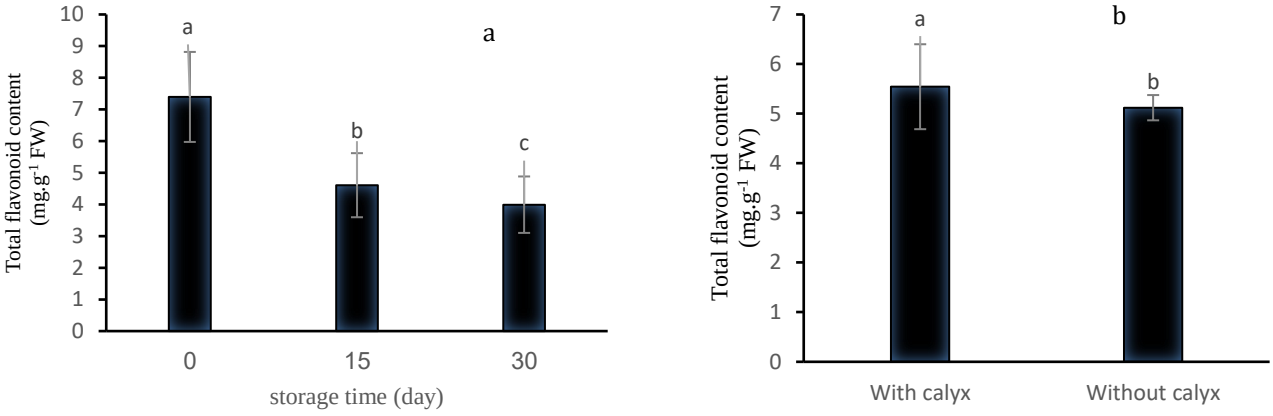

Fig. 1. Effects of calyx coating and storage time on flavonoid content in Cape gooseberry

Discussion

The postharvest storage of fruits is one of the main drivers of the food industry. Fruit loss can occur quantitatively and qualitatively between harvest and consumption (Liato et al., 2017). On the other hand, berry harvesting at the full maturity stage helps maintain fruit quality because the berries usually show high acidity at their peak of maturity (Rincón et al., 2016).

An analysis of variance regarding the changes in physicochemical traits of Cape gooseberry during storage (Table 1) showed physicochemical changes in the first 30 days of storage and during the entire storage period. The results showed that the interaction effects of different levels of calyx coating, storage temperature, and storage time were significantly observable on the soluble solids content, titratable acidity, flavor index, total phenol, and total antioxidant.

The amount of soluble solids is one of the important factors in the quality of fruits, and sometimes these substances can ultimately reduce the quality and marketability of the product (Hu et al., 2011). The interaction effects of temperature, calyx coating, and storage time on the soluble solids content showed that increasing the storage time at 10 °C had a positive effect compared to the other temperatures. With increasing the temperature during the storage time, the soluble solids were substantially reduced, due to their consumption in respiration and energy supply for energy-consuming processes (Lo Piero et al., 2005). In addition, increasing the temperature during different times of the storage actually increased the respiration rate, so it can be concluded that a high storage temperature reduces the titratable acidity (Piga et al., 2000). The reduction in total acid content in the berries with calyx was less than the decrease in berries without calyx, which can be due to the fact that the berries continue to derive carbohydrates and nutrients from the calyx coating after harvest. The calyx coating plays a nutritional role in the fruit and during storage. In berries with calyx, this helps maintain the acid available for titration during storage. It seems that the decrease in the amount of organic acids in berries without calyx at high temperatures is

due to water loss and increased respiration rates because any decrease in the moisture content of fruits would usually reduce the consumption of organic acids and help maintain the quality of fruits (Chen et al., 2007).

The ratio of sugar to acid is conventionally regarded as a factor in determining the flavor index of berries. According to the results, the berry flavor index increased through the 30-day storage period (Table 1). Our results are consistent with previous research by Kane et al. (2008). Other researchers also found that the amount of TA decreased as a result of respiration and also because of the transformation of tartaric acid into other materials during the storage period (Rapisarda et al., 2008). On the other hand, the calyx retained more acidity in berries, compared to the condition of the control, which corresponded with a previous work on orange fruits by Rasouli et al. (2019). This may be due to the slow conversion of acids to sugar upon maturity (Kumar et al., 2017). Moreover, the effects of storage time on total acid reduction was more than the effects on the decrease of soluble solids during storage at different temperatures. As a result, the cause of the increase in the flavor index can be attributed to an increase in soluble solids and a decrease in total acidity during fruit ripening and storage time (Ladaniya et al., 2003). During the process of respiration and through the time of storage, vitamin C is highly susceptible to decomposition due to oxidation, compared to other nutrients in the fruit. The vitamin C content declined over time and, after 30 days, the greatest decrease was observed. Moreover, with increasing the temperature, these changes also exacerbated. This reduction in vitamin C, especially during long-term storage, seems to be natural because the increase in storage duration further led to the aging phenomenon, so that vitamin C and acids were incorporated into the respiratory and Krebs cycles (Lee and Kader, 2000). The results showed that vitamin C was destroyed during storage. In this case, it has been reported that ascorbic acid is a precursor to the production of brown pigments, and the change in the amount of ascorbic acid causes browning of the tissue, which ultimately causes the loss of the quality of berries (Biolatto et al., 2006). It seems that ascorbic acid accumulates in berries during the process of fruit ripening, but its increase is sharper in the berries that remain on the plant, compared to those that are harvested at the green or yellow stages. High titratable acid is an ascorbic acid stability factor in assessing the chemical profile of berries. The occurrence of high acidity in fruits can contribute to a relatively stable ascorbic acid content during post-harvest storage (Tavarini et al., 2007). It has been reported that the decrease in vitamin C can be attributed to the decrease in the antioxidant capacity of berries during storage (Arena et al., 2001). Researchers also believe that decreasing vitamin C levels at the end of storage may be due to a reduction in water content that leads to the oxidation of vitamin C (Amodio et al., 2007).

In higher plants, abiotic stresses (e.g. salinity, drought, heat, cold, and light) are responsible for oxidative stress (Sreenivasulu et al., 2007). Blokhina et al. (2003) showed that an accumulation of high concentrations of ROS is potentially harmful to plant cells and can damage biological molecules such as DNA, proteins, lipids, chlorophyll, and membranes. Considering that the highest amounts of total antioxidants were observed in the first stage of sampling, i.e. immediately after harvest, this index declined parallel to increasing storage temperature. However, the calyx on berries prevented the further reduction of antioxidant capacity. It should be noted that the low temperature of storage caused oxidative stress and, thus, the antioxidant system played a role in reducing the stress. Our research showed a significant relationship between total phenol content and flavonoids, but depending on the materials and the temperature of storage, the changes occurred differently in the phenolic compounds and the antioxidant properties. One of the most important antioxidant substances is vitamin C, which decreases during storage (Sharma et al., 2015). In the present study, total antioxidant properties during storage reduced over time due to the oxidation of phenolic compounds and flavonoids, which were consistent with the results of previous research (Bolling et al., 2010). Plant cells employ different methods to reduce the damage of cold, and the development of the antioxidant system is one of these defensive strategies in plants. Phenolic substances, which are a group of antioxidant compounds, are used as electron donors for oxidants to neutralize free radicals (Lee et al., 2003). Since the calyx covers the berries, it also plays a nutritional role and contributes to the respiration process. In berries with calyx, thus, phenolic substances inside the berry flesh are consumed less during respiration. Phenolic compounds, especially flavonoids and flavonols, due to their strong antioxidant properties, can reduce oxidative stress by trapping free radicals (Galani et al., 2017). These compounds play their antioxidant role, with various mechanisms, such as scavenging free radicals and donating hydrogens, turning off singlet oxygen, chelating metal ions, or working in collaboration with peroxides in the collection or

removal of hydrogen peroxide (Rutz et al. 2012). In this study, the increase in phenolic compounds over time seemed to be the strategy of cells to cope with oxidative stress. In addition, flavonoids are one of the most extensive and diverse natural compounds that can absorb free radicals like other phenolic compounds. At times of oxidative stress, phenolic compounds, especially flavonoids, can interact with phospholipids through a hydrogen bond with polar heads of phospholipids. These compounds accumulate on the inside and outside of the membrane and help maintain the fluidity and membrane integrity of the membrane to prevent the release of harmful molecules into the dipole hydrophobic region (Sakihama et al., 2002). Due to the prominent presence of flavonoids in this plant species, it can be concluded that a part of its protective effects is exerted by strengthening the antioxidant system and inhibiting ROS production.

Conclusion

The purpose of this study was to evaluate the effects of calyx cover and storage conditions on the storage quality of Cape gooseberries. At the end of storage, the titratable acidity, total soluble solids, vitamin C, total flavonoids, and total antioxidants decreased. However, the total phenol content and flavor index increased during storage, which could be due to a significant reduction in the titratable acidity (regarding the flavor index), the destruction of fruit cells, and the adverse effects of cold damage (regarding total phenol). In addition, at the end of the storage period, berries with calyx, which were stored at 10 °C for 30 days, showed an agreeable physicochemical profile and had a suitable antioxidant capacity. The highest titratable acidity, soluble solids, vitamin C, and total antioxidant were observed in berries with calyx coatings at the storage temperature of 10 °C. For future research, it is recommended that the effects of harvesting stages and different storage temperatures be evaluated on the changes of color indices in Cape gooseberries.

Conflict of interest

The authors indicate no conflict of interest in this research.

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